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Abstract

DEVELOPMENT OF ORGANIC LIQUID COOLANTS

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1. Research and development work, mainly in fuel-test loops in the NRX and NRU reactors, shows that organic liquids are promising media for transporting heat from reactors, that their purity can be maintained in the presence of radiation and heat fluxes, and that structural materials are available that are compatible with these liquids.

2. Thermal and radiolytic decomposition rates of individual terphenyls and of mixtures have been measured over the temperature range from 150 to 475°C. For the same energy deposition, fast neutrons cause about three times as much damage as electrons. Decomposition rates have also been measured for other liquids which have melting-point properties suitable for initial reactor start-up. One, a partially hydrogenated terphenyl mixture, had a decomposition rate about the same as that of the terphenyls but a gas-formation rate about three times higher.

3. Continuous purification of the liquid is essential. Chlorine in the terphenyl used for make-up varies from 2 to 10 ppm and the amount in the bulk system must be kept below about 5 ppm. Chlorine can be removed on beds of magnesium turnings or of palladium on alumina granules heated above 325°C; in routine operation of loops the level can be kept below 3 ppm. Other impurities are removed by adsorption on beds of attapulgus clay at 325°C. Particulate matter must be kept to a minimum by filtration, e.g., through glass-wool filters. Water and hydrogen can be removed by gas stripping, and, while the hydrogen should be kept low, reasons exist for controlling the water at a level around 100 ppm.

4. Two types of fouling on fuel-element surfaces have been recognized. The first type gives a deposit containing over 70% iron with essentially no organic matter. It is formed by the transfer of iron from the circuit piping at about 300°C to the hot fuel-element surface at 400 - 500°C. Chlorine, most of which resides on the system walls, plays an important role in the transfer. If the total chlorine in the system is less than the equivalent of 3 ppm in the coolant, this mass-transfer effect is acceptably low.

The second type of fouling is caused by organic particles in the coolant and gives a deposit high in organic matter. High surface temperatures increase the amount of this type of fouling, but irradiation appears not to influence it greatly. Recent experience in the X-7 loop in the NRX reactor showed that after 82 days irradiation in a thermal-neutron flux of about 5×10^{13} cm^{-2} s^{-1}, the fouling film on fuel sheaths maintained at 450 to 500°C was less than 1 μm thick.

5. Zirconium alloys are shown to be compatible with organic coolants provided the coolant conditions are correct. Chlorine promotes rapid hydriding, but when the chlorine content is kept below 3 ppm the effect is markedly decreased. The concentration of water is also very important, since, if it is too low, an oxide film impermeable to hydrogen is not maintained; the optimum water concentration is probably about 100 ppm. The longest test was of a Zircaloy-4 pressure tube in the X-7 loop. After 10 months of irradiation with a coolant outlet temperature of 350 - 390°C and a low water concentration (10 - 50 ppm) the maximum hydrogen pick-up by the alloy was about 80 ppm. There was some evidence of higher pick-up in regions of higher flux.